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Potato Flea Beetles and Their Control

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POTATO FLEA BEETLES AND THEIR CONTROL

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INTRODUCTION

Flea beetles cause greater damage to potatoes in Ohio than any other group of potato foliage attacking insects. Year after year, unless these insects are controlled by means of sprays or dusts, they consistently cause significant reductions in both the quality and quantity of the tuber crop.

Some years ago, the Colorado potato beetle and the black blister beetle were the outstanding potato foliage destroying pests. At the present time natural agencies of control, principally parasitic and predaceous insects, hold these pests in check to the extent that neither is troublesomely abundant except on infrequent occasions.

This bulletin summarizes the research activities of the Department of Entomology in the potato flea beetle project for the 5-year period from 1930 to 1934, inclusive. The control aspects of the problem have been given the greater emphasis; however, certain imperfectly understood biological phases have received some attention and will be given brief mention. An exhaustive description of the several species of flea beetles and their habits will not be attempted, because it is assumed that Ohio potato growers are fully well acquainted with these pests.

SPECIES OF FLEA BEETLES

The two most important species of flea beetles occurring on potatoes in Ohio are *Epitrix cucumeris* Harris, commonly known as the potato flea beetle, and *E. parvula* (Fab.), the tobacco flea beetle. The egg plant flea beetle, *E. fuscula* Crotch, undoubtedly is present, but it is unimportant as far north as Wooster. The pale-striped flea beetle, *Systena blanda* Melsh., and the smartweed flea beetle, *S. hudsonias* Forster, may also be found in potato fields; the latter sometimes appears in numbers to cause severe injury.

LIFE HISTORY

HIBERNATION

The potato flea beetle and the tobacco flea beetle hibernate in the adult stage in the soil under the protection of a surface covering of vegetable debris. It has been generally stated by others that such covering is necessary for successful survival. This belief is borne out by experience obtained in tests made at Wooster, Ohio, during the winters of 1932-1933 and 1933-1934 with the two species named. For the purpose of this experiment, six wooden framework cages were constructed, each 2 feet wide, 6 feet long, and 3 feet high. An 8-inch metal strip extending downward from the sides of the cage was sunk into the soil. The sides and top of the cage were covered with cheesecloth. The cages were placed in an open field. The beetles to be used were collected in the late fall and placed in the cages as soon as possible after they were captured. A suction device was used for capturing the insects in order to avoid injury. Around each cage where a ground covering was provided, a 3-foot area was covered with 3 inches of straw held in place with loose earth.

The cages and their contents were allowed to remain undisturbed throughout the winter and spring. With the advent of warmer weather, daily visits were made to determine the extent of the activity of the insects in the cages, and all actively moving beetles were removed. In Table 1 are indicated the type of ground cover used, the number of beetles in each cage, and the percentage which survived in the 1932-1933 test.

TABLE 1.—Hibernation of Potato and Tobacco Flea Beetles under Different Conditions During Winter of 1932-1933

Ground coverage	Number of beetles introduced Sept. 1-13	Survival	
		Number	Percentage
Heavy sod, grass not cut	4000	14	0.35
Heavy sod, hay removed	4000	18	0.45
Bare ground	4000	3	0.075
Three to 4 inches of elm leaves	4000	61	1.53
Three to 4 inches of green potato vines	4000	60	1.50
Three to 4 inches of wheat straw	4000	65	1.63

The cages used in 1933-1934 were prepared as during the previous year, but those without ground coverage were eliminated. Table 2 gives the results of this test.

TABLE 2.—Hibernation of Potato and Tobacco Flea Beetles under Different Conditions During Winter of 1933-1934

Ground coverage	Number of beetles introduced Sept. 15-25	Survival	
		Number	Percentage
Three to 4 inches of tree leaves	5000	44	0.88
Three to 4 inches of green potato vines	5000	13	0.26
Three to 4 inches of wheat straw	5000	18	0.36

The percentage of survival under cage conditions was decidedly low during both seasons this experiment was conducted. Undoubtedly the hibernating instinct of the insect is such that it seeks more favorable quarters than those provided in these tests, and in all probability the percentage of survival under natural conditions is considerably greater. There is a further possibility that normally the beetles seek their hibernating quarters a little later in the season than the time of capture of the insects used in these tests. Had it been possible to allow a little longer period for feeding, perhaps the resulting increase in stored vitality would have enabled a larger number of the beetles to survive. This statement is based on the fact that in the fall of 1932 potatoes had been planted in the cages to provide food until the vines were killed by freezing temperatures. A higher percentage of survival was experienced in that year than in the following one when no food was provided.

SPRING EMERGENCE

The beetles in the cage experiments began to leave hibernation in May and continued to appear as late as July. Figure 1 shows the daily emergence records for the two seasons. The peak of emergence takes place during the first week of June. The cage records correlate very closely with field observation data, since in both years the first appearance of the beetles in the cages and in the field took place at the same time.

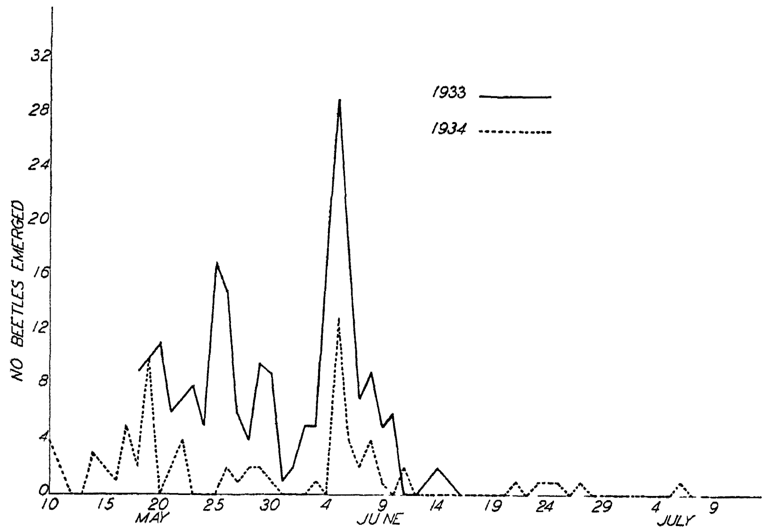

Fig. 1.—Seasonal emergence from hibernation of caged beetles, 1933 and 1934

IMMATURE STAGES

The eggs of the potato flea beetle are deposited in moist soil at depths of ½ to 2 inches. In Colorado, according to Hoerner and Gillette[1], the average incubation period was 9.82 days when the eggs were kept moist. The extremes of the period were 5 and 13 days. In Kentucky, according to Jewett[2], the period was somewhat shorter, having a mean of 6.3 days and a range of 5 to 10 days.

The larvae feed upon subterranean plant parts. In both the Colorado and Kentucky records, 25.7 days were given as the average length of the larval period for the first brood. Jewett found that the second-brood larvae required an average of 20.6 days for their development.

Pupation occurs in the soil. In Colorado an average period of 9.72 days was required for the pupal period. In Kentucky the period was shorter. It averaged 7 days for the first brood and 6 days for the second.

On the basis of the foregoing observations it appears that the combined egg, larval, and pupal stages require approximate periods of from 30 to 40 days for their completion.

NUMBER OF GENERATIONS

Detailed life history studies by Hoerner and Gillette[1] indicate that each year in Colorado there are one complete generation and an extremely slight second. Two generations are characteristic of both species in Kentucky accord-

[1]Hoerner, J. H. and C. P. Gillette. 1928. The potato flea beetle. Colo. Agr. Exp. Sta. Bull. 337.

ing to Jewett[2]. In the vicinity of Wooster, Ohio, there are one full generation each season and a partial second one; thus, some of the beetles of the first brood and all of the second constitute the overwintering generation.

The first adults of the first generation of the season appear in the locality of Wooster, Ohio, in July. In 1933, the insects were much delayed and none of this brood appeared before July 28, but in both 1930 and 1934 the first-brood beetles appeared as early as July 16 and were very abundant. A study of the collection records presented in Tables 20 and 21 will substantiate this statement.

As a rule, many beetles of the overwintered generation remain alive until those of the first generation appear; thus the two broods intermingle. The second-generation beetles are produced by the earliest individuals of the first generation. These second-generation adults may be found in late August and others may not appear until September.

INJURY DONE BY FLEA BEETLES

The damage done by flea beetles to the potato crop in Ohio is confined almost entirely to the foliage. In some sections of the United States, flea beetles are more important from the standpoint of damage done by the larvae to the tubers than from that of damage done to the leaves. Only rarely does tuber injury occur in this State. An injured potato leaf is shown in Figure 2.

HOST RELATIONSHIP

The flea beetles which attack potatoes feed upon a wide range of host plants. Approximately 50 hosts are listed, but of these only a few are seriously injured. The most important crops attacked are potato, tomato, tobacco, egg plant, pepper, and cucumber.

PREVAILING WEATHER CONDITIONS 1930-1934

The weather conditions prevailing during the period in which this work was conducted varied considerably from normal. In 1930, 1932, and 1933 the rainfall was below normal, but in 1931 the monthly precipitation and the total were both above normal. Data relative to summer rainfall are given in Table 3.

TABLE 3.—Rainfall at Wooster*

1930-1934, inclusive

	May	June	July	August	September	Total
	In.	*In.*	*In.*	*In.*	*In.*	*In.*
50-year mean	3.76	3.94	4.05	3.62	3.29	21.70
1930	1.59	2.86	1.71	2.64	2.53	13.56
1931	4.45	3.49	2.97	4.68	3.48	23.17
1932	1.93	3.44	3.14	2.01	1.98	15.00
1933	4.77	1.67	1.73	3.85	4.23	19.72
1934	0.43	4.50	2.55	4.21	6.11	20.60

*Adapted from Ohio Agr. Exp. Sta. Bull. 544.

The years which were characterized by light precipitation also had excessive temperatures. Each month of the growing season of the years 1930, 1932, and 1933 had a mean temperature above normal; in 1931 it was somewhat below. These data are given in Table 4.

[2]Jewett, H. H. 1929. Potato flea beetles. Ken. Agr. Exp. Sta. Bull. 297.

TABLE 4.—Mean Temperatures at Wooster*
1930-1934, inclusive

	May	June	July	August	September	Summer mean
	° F.	° F.	° F.	° F.	° F.	° F.
44-year mean	58.6	67.6	71.8	69.8	64.1	66.4
1930	61.1	69.0	73.9	70.5	66.7	68.2
1931	57.4	67.7	75.6	71.8	58.4	66.2
1932	58.8	68.9	72.0	70.8	64.6	67.0
1933	61.8	72.4	73.8	70.6	67.2	71.4
1934	62.4	74.4	76.6	69.5	66.1	69.8

*Adapted from Ohio Agr. Exp. Sta. Bull. 544.

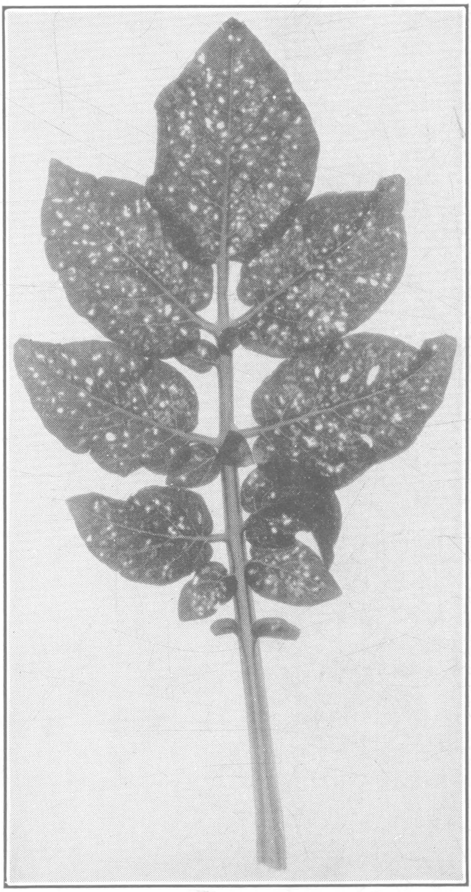

Fig. 2.—A potato leaf injured by flea beetles

Weather conditions which vary from the normal affect both the crop and the insects attacking it. From the data obtained, it appears that during seasons of above-normal rainfall potatoes suffer less from insect attack than during the seasons when rainfall is deficient. In 1931, when the rainfall was above normal, smaller differences were found between the variously treated plots than in 1930 and 1932, when the precipitation during the growing season was less than the long-time average. In 1933, when the rainfall in June and July was far below the usual amount, the crop was almost a complete failure and the differences between treatments were small.

CONTROL INVESTIGATIONS

Prior to the inauguration of this project, only a small amount of field work had been conducted anywhere on the control of flea beetles attacking potatoes. The program of 1930 was the first attempt to evaluate work of this sort from the standpoint of effect on yield[3]. Hoerner and Gillette reported that 5 days after an application of a spray consisting of 3 pounds of calcium arsenate, ¾ pound of calcium caseinate, and 100 gallons of water, flea beetle populations were reduced 85 per cent and that after an 11-day period populations were reduced 95 per cent.

The control aspects of this investigation were centered around the regular Bordeaux mixture sprays as recommended for controlling leafhoppers and certain potato diseases. To this mixture were added certain arsenicals and a fluorine compound. These were applied under different conditions which included variations in number of treatments, season of application, and strength of materials. Further digressions involved the use of copper-lime dust and of pyrethrum sprays.

In all instances the data secured have been evaluated through the use of recognized statistical devices and particularly that known as "analysis of variance"[4]. The differences required for significance and the odds at which they are considered are given in footnotes for each table.

In all instances the field work was done in cooperation with growers, who generously allowed the use of their equipment, labor, and growing crops. Some of the sprayers used were of the traction type and others were of the engine-driven pump type. The traction sprayer used developed a pressure of 275 pounds per square inch and the power sprayers from 300 to 350 pounds. The booms with three nozzles per row were carefully adjusted to yield the best possible coverage. The experience gained in this work, as well as that of growers, indicates that good coverage is absolutely essential to success in flea beetle control. Coverage depends upon adequate allowances of material per acre, sufficient pressure, and proper nozzle arrangement.

The dusting equipment employed likewise was grower-owned. The same care relative to coverage was exercised.

EFFECT OF PYRETHRUM SPRAYS ON FLEA BEETLE POPULATIONS

In 1931, a 4-acre field of Russet Rural potatoes heavily infested with flea beetles was chosen for testing pyrethrum sprays. This field was located on the farm of Hoover Brothers, in Geauga County. It was divided into three parts of approximately equal size. The middle section was left unsprayed. One

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[3]Gui, Harry L 1932 Flea beetle investigation, 1930-1931. Proceedings Seventeenth Ann. Meeting Ohio Vegetable Growers' Assoc., pp. 62-67.

[4]Fisher R. A 1932. Statistical Methods for Research Workers. Fourth Edition. Oliver and Boyd, London.

section was sprayed with Evergreen 1-200 with 0.25 per cent Penetrol added to the solution, and the other section was sprayed with Penethrum at the rate of 1-200 without spreader.

The sprays were applied on June 30, which was a sunshiny, warm day. A four-row power sprayer equipped with a Nixon-type boom having three nozzles per row was used. This sprayer developed a pressure of about 350 pounds per square inch. Approximately 125 gallons of spray were applied to each acre.

Within 5 minutes after the sprays had been applied, all the beetles which previously had not been washed from the plants had fallen to the ground where they at once buried themselves. However, within 30 minutes, beetles began to reappear on the plants, but whether they were individuals that had been hit with the spray and had revived, or whether they were others that had migrated in from the unsprayed portion of the field could not be determined.

Population counts were made on the next day. This was done in the following manner: A cloth sheet was carefully spread on each side of three adjacent hills and a square, open-bottom, boxlike cover was inverted over the three plants. Calcium cyanide was introduced through a hole in the cover to stupefy

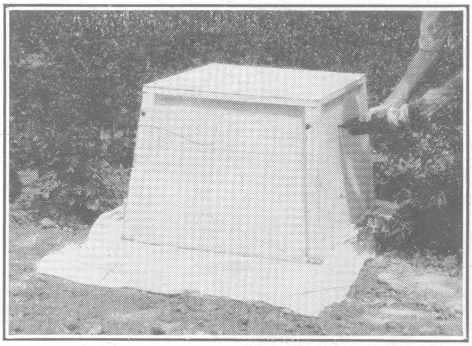

Fig. 3.—Apparatus used for determining flea beetle populations by the calcium cyanide method

the beetles on the plants. In a short time the beetles fell from the plants upon the sheets, where they could easily be counted. The apparatus used is shown in Figure 3. To eliminate as much error as possible in the time element, sampling was done progressively back and forth across the plots. Three samples were taken from one plot before moving to the next.

The results of these counts are given in Table 5.

Although a considerable reduction in population resulted from the use of these two pyrethrum sprays, it cannot be said that a commercial control was obtained.

After 72 hours, the count was repeated. The data secured are given in Table 6.

It will be observed by comparing Tables 5 and 6 that the differences in population between the sprayed and unsprayed plots, which were apparent at the time the records were taken 1 day after treatment, had wholly disappeared after 3 days' time. The interpretation placed on this condition was that although the sprays had killed some of the beetles, the infestation throughout

TABLE 5.—Flea Beetle Populations on Lots of Three Plants Each

Twenty-four hours after spraying

Replicate	Treatment		
	No spray	Penethrum 1-200	Evergreen 1-200 Penetrol 0.25%
1	103	75	78
2	79	49	79
3	30	55	28
4	135	50	55
5	112	81	79
6	71	118	23
7	93	64	25
8	101	64	58
9	65	70	64
10	25	35	32
11	22	26	23
12	72	21	36
13	30	26	24
14	44	30	37
15	34	22	49
Mean*	67.7	52.4	46.0

*A difference of 6.1 is required for significance at 49:1 odds.

TABLE 6.—Flea Beetle Populations on Lots of Three Plants Each

Seventy-two hours after spraying

Replicate	Treatment		
	No spray	Penethrum 1-200	Evergreen 1-200 Penetrol 0.25%
1	59	36	31
2	25	35	55
3	30	55	29
4	52	33	67
5	32	48	50
6	69	23	42
7	17	51	82
8	37	21	40
9	76	57	36
10	67	47	62
11	57	48	68
12	18	63	41
Mean*	44.9	43.0	50.3

*A difference of 18.8 is required for significance at 49:1 odds.

the field had been equalized by the migration of beetles from the unsprayed plot to the sprayed plots, inasmuch as the population of the unsprayed plot had decreased perceptibly during the interval between the 1-day and 3-day records. This assumption is substantiated, in part at least, by the fact that 1 day after treatment the average population on all three-plant samples in both sprayed and unsprayed plots was 55.6 beetles per sample; whereas the average population at the end of the 3-day period was 44.5 beetles per sample. In fact, because of the general decrease in population throughout the field as a whole, it might be assumed that additional numbers of beetles succumbed in the sprayed plots during the interval between the taking of the 1-day and 3-day records.

In order to evaluate further the pyrethrum sprays and in an endeavor to eliminate the confusion due to migration from unsprayed plots, several small fields were chosen at Wooster in which the entire field was sprayed with a single material.

A six-row power sprayer developing 300 pounds of pressure with three nozzles per row was used. Approximately 100 gallons per acre were applied. A record of normal populations was obtained before the spray applications were made and the populations were again determined at various intervals following the sprays. The data collected are given in Table 7.

TABLE 7.—Flea Beetle Populations Following Various Sprays

Treatment	Population of individual plants (average of 10 plants)						
	Before spraying	After spraying					
		1 day		3 days		7 days	
		Number	Per cent reduction	Number	Per cent reduction	Number	Per cent reduction
Bordeaux mixture........ Calcium arsenate 2–50...	106	29	73	24	77	14	87
Penethrum 1–200..........	43	40	14	46	0	23	47
Evergreen 1–200......... Penetrol 0.5%....	89	51	42	53	41	32	63
Evergreen 1–300......... Penetrol 0.5%..........	156	60	62	57	63	83	47

It will be noted that where Bordeaux – calcium arsenate was used there was a continuous and progressive decrease in the number of beetles on the plants; whereas where the pyrethrums were used the populations were not diminished greatly after the first day. This indicates further that the leveling-off of the populations in the tests on the Hoover farm was due to migration rather than to the recovery of the beetles after the application of pyrethrum sprays.

EFFECT OF STOMACH POISONS ON YIELD

An important phase of this investigation which extended throughout the entire 4-year period was that of noting the effect on yield of the stomach poisons that were incorporated in the regular program of Bordeaux sprays. The possibility of such a combination appealed strongly to the growers because of its very obvious practicability.

Work with stomach poisons was conducted at three places. At Wooster the work was done in cooperation with the late Mr. Edgar Frick and his tenant, Mr. Levi Dilyard. At Bolivar in northern Tuscarawas County, where flea beetle damage is normally extensive, the work was done in cooperation with Mr. Erwin Kline. Dusting tests were conducted on the Horr-Warner muck land at Creston in cooperation with Mr. H. R. Benton. The excellent assistance given by these men was of great aid in carrying out this program.

At each place the tests were planned so that they would not interfere with regular farm practice. This necessitated the use of large plots. The treatments in each instance were replicated at complete random. Previous experience had shown that without ample replication and randomization it was not possible to measure the effectiveness of control measures applied against flea beetles. With a very few exceptions the treatments were applied under the supervision of a representative of the Department of Entomology.

Since the ultimate end sought in work of this sort is increased yield at the lowest cost, the effect of the various spray practices upon yield will be discussed first. Following this, supplementary matter will be presented which indicates that the yield increases were due to flea beetle control.

STOMACH POISONS IN SPRAYS

In 1930 the work was confined to Cobbler potatoes in the Wooster area. Four treatments consisted of 4-6-50 Bordeaux to which a poison was added and two treatments consisted of Bordeaux alone prepared after the 4-6-50 and the 6-10-50 formulas, respectively. The stomach poisons were used at the rate of 2 pounds to 50 gallons of spray material. Nine applications of sprays were made but the arsenicals were not included in all, as is indicated in Table 8.

The sprays were applied with a traction sprayer which developed a 300-pound pressure. The four-row boom was equipped with three nozzles per row. The rate of application was 125 gallons per acre. Beginning on June 4, the sprays were applied at as nearly weekly intervals as possible.

The rows were 60 rods in length and 32 inches apart. Eight rows constituted a plot. Thus, each plot covered an area of ½ acre. Yield samples were obtained by harvesting the entire crop of the two middle rows of each plot.

The different spray formulas employed and the effect of each one upon yield are given in Table 8.

TABLE 8.—The Spray Schedules and the Effect upon the Yield of Cobbler Potatoes at Wooster in the 1930 Spray Tests

Treatment*	Yield per acre				
	Replicate				Mean†
	1	2	3	4	
	Bu.	*Bu.*	*Bu.*	*Bu.*	*Bu.*
Calcium arsenate in first six sprays	152	169	163	155	160
6-10-50 Bordeaux, no poison	161	149	168	137	154
Lead arsenate in first six sprays	157	146	142	140	146
Lead arsenate in first three sprays	142	144	154	135	144
Calcium arsenate in first three sprays	154	134	133	144	141
4-6-50 Bordeaux, no poison	147	122	138	117	131

*In every instance where poisons were applied, they were combined with 4-6-50 Bordeaux. All poisons were used at the rate of 2 pounds per 50 gallons of spray.

†A difference of 7.44 is required for significance at 19:1 odds.

All stomach poisons proved better than the check treatment of 4-6-50 Bordeaux. Calcium arsenate in six sprays was significantly superior to the other stomach poisons. The plots which received 6-10-50 Bordeaux yielded high, but it will be shown later that this was not due to flea beetle control.

In 1931, two fields of Russet Rural potatoes were included in the tests. One field was located at Wooster and the other at Bolivar. The program of eight sprays used and yield data obtained in the Wooster test are shown in Table 9. The plots were randomized and replicated four times. Eight-row plots, each containing ½ acre, were used and the yields were taken from the two middle rows of each plot. In this test, the equipment described under the 1930 test was used. Spraying began June 10 and was concluded August 17.

TABLE 9.—Spray Schedule and Yields of Russet Rural Potatoes at Wooster in the 1931 Spray Tests

Treatment*	Yield per acre				
	Replicate				Mean†
	1	2	3	4	
	Bu.	*Bu.*	*Bu.*	*Bu.*	*Bu.*
Calcium arsenate in eight sprays	198	261	297	281	261
Calcium arsenate in last four sprays	261	225	243	288	254
4-6-50 Bordeaux, no poison	198	243	261	243	236
6-10-50 Bordeaux, no poison	216	207	216	306	236
Lead arsenate in first four sprays	234	189	252	252	232
Calcium arsenate in first four sprays	225	207	243	243	230
Lead arsenate in eight sprays	234	252	207	225	230

*In every instance where poisons were applied, they were combined with 4-6-50 Bordeaux mixture. All poisons were used at the rate of 2 pounds to 50 gallons of spray. A total of eight sprays was applied to each plot.
†A difference of 49.2 is required for significance at 19:1 odds.

In this test, the highest yield was produced by the plots which had received calcium arsenate in all of the eight sprays. From these data, it is inadvisable to draw conclusions, because there is no statistical difference between the mean yields of any of the treatments. The test is indicative, however, in that the treatment which produced the highest yield is the same as that which in other tests had proved to be superior.

The test in the Bolivar area was very similar to the Wooster test. Each plot consisted of eight rows spaced 30 inches apart and contained about ⅗ acre. The treatments were replicated four times and the plot arrangement was completely randomized.

A four-row power sprayer which produced a pressure of 300 pounds was used. The boom was equipped with three nozzles per row which applied the spray at the rate of 125 gallons per acre. The first of the eight sprays was applied on June 18 and the last, on August 24.

The yield was determined by harvesting the entire crop from the middle two rows of each plot. From these data the acre yield was calculated. The results are given in Table 10.

TABLE 10.—Spray Schedule and Yields of Russet Rural Potatoes at Bolivar in the 1931 Spray Tests

Treatment*	Yield per acre				
	Replicate				Mean†
	1	2	3	4	
	Bu.	*Bu.*	*Bu.*	*Bu.*	*Bu.*
Calcium arsenate in eight sprays	223	197	236	249	226
Lead arsenate in eight sprays	194	171	229	239	208
Calcium arsenate in first four sprays	191	165	229	233	205
Lead arsenate in first four sprays	191	142	216	245	199
4-6-50 Bordeaux, no poison	158	191	181	192	181
Calcium arsenate in last four sprays	158	184	216	216	169

*In every instance where poisons were applied, they were combined with 4-6-50 Bordeaux. All poisons were used at the rate of 2 pounds to 50 gallons of spray. A total of eight sprays was applied to each plot.
†A difference of 30.6 is required for significance at 19:1 odds.

In this test, as in the two preceding ones, the use of calcium arsenate throughout the season resulted in the highest yield. In all instances where comparative numbers of treatments were made, plots which received lead arsenate did not yield as heavily as those treated with calcium arsenate.

An interesting difference occurred between the Bolivar and Wooster tests. At Bolivar the potato crop was thrifty and grew rapidly early in the season; whereas at Wooster the crop was slow in starting and made the maximum vine growth late in the season. At Wooster, the late application of calcium arsenate gave a decided increase in yield, but at Bolivar, where the growth was early, calcium arsenate in the last four applications did not increase the yield.

In 1932, three fields were under test. One field of Russet Rural potatoes was located at Wooster and another at Bolivar. A field of Cobbler potatoes was under test at Wooster.

The plot size at Wooster was reduced to four rows and the number of replications increased to five. The rows were 32 inches apart and each four-row plot occupied an area of ⅛ acre. The entire crop from the two middle rows constituted a sample for calculating the yield record. The first of eight sprays was applied on June 8 and the last, on August 2.

The sprayer used was a four-row power machine, equipped with three nozzles to each row, which produced a pressure of 350 pounds per square inch. Approximately 100 gallons of spray were applied per acre.

The data on yield of Russet Rural potatoes are given in Table 11.

TABLE 11.—Spray Schedules and Yields of Russet Rural Potatoes at Wooster in the 1932 Spray Tests

Treatment*	Yield per acre					
	Replicate					Mean†
	1	2	3	4	5	
	Bu.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
Calcium arsenate in eight sprays	165	165	204	193	223	190
Lead arsenate in eight sprays	176	194	189	182	174	183
Calcium arsenate in sprays 1, 3, 5, and 7	165	175	161	180	186	173
Calcium arsenate in last four sprays	179	195	153	149	161	167
4-6-50 Bordeaux, no poison	152	168	170	150	152	158
Barium fluosilicate in eight sprays	144	164	168	161	142	156

*In all instances where poisons were applied, they were combined with 4-6-50 Bordeaux. All poisons were used at the rate of 2 pounds to 50 gallons. A total of eight sprays was applied to each plot.

†A difference of 22.0 is required for significance at 19:1 odds.

Plots which received eight applications of Bordeaux mixture and calcium arsenate produced the highest yield. Plots treated with lead arsenate throughout the season produced more than those treated with calcium arsenate either in alternate applications or in the last four of the season. Barium fluosilicate apparently had no effect on the yield.

At Bolivar, the sprays were applied with the same equipment used in 1931. Eight-row plots were used, and the yield records were taken from the two middle rows of each the full length of the field. Each plot contained slightly less than ½ acre. Eight sprays were applied; the first, on June 7 and the last, on August 12. Two subsequent sprays of 4-6-50 Bordeaux were applied to each plot. The data are given in Table 12.

TABLE 12.—Spray Schedules and Yields of Russet Rural Potatoes at Bolivar in the 1932 Spray Tests

Treatment*	Yield per acre				
	Replicate				Mean†
	1	2	3	4	
	Bu.	*Bu.*	*Bu.*	*Bu.*	*Bu.*
Calcium arsenate in eight sprays	141	132	163	168	151
Calcium arsenate in last four sprays	135	138	149	150	143
Calcium arsenate in sprays 1, 3, 5, and 7	128	119	143	149	135
4-6-50 Bordeaux, no poison	127	135	128	149	135
Calcium arsenate in first four sprays	133	109	115	147	126
Lead arsenate in eight sprays	138	113	131	131	126
Barium fluosilicate in eight sprays	138	85	133	134	123

*In all instances where poisons were applied, they were combined with 4-6-50 Bordeaux. Poisons were used at the rate of 2 pounds to 50 gallons of spray.

†A difference of 19.3 is necessary for significance at 19:1 odds.

In this test, plots treated with calcium arsenate produced higher yields than did those which received other treatments. Those treated with lead arsenate and barium fluosilicate did not differ statistically from any other treatment except the one in which calcium arsenate was used in eight sprays.

In 1932, the test on Cobbler potatoes produced data which do not agree with data presented on the preceding pages. In this test, four-row plots were used; each covered an area of ¼ acre. Treatments were made with the same equipment used on Russet Rural potatoes at Wooster in 1932. Spraying operations continued from June 8 to August 2, during which time a total of eight applications was made. The last two of these consisted of 4-6-50 Bordeaux without poison.

The yield data obtained from this field are given in Table 13.

TABLE 13.—Spray Schedules and Yields of Cobbler Potatoes at Wooster in the 1932 Spray Tests

Treatment*	Yield per acre					
	Replicate					Mean†
	1	2	3	4	5	
	Bu.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
Lead arsenate in six sprays	163	176	98	137	102	135
Barium fluosilicate in six sprays	156	179	130	110	90	133
Calcium arsenate in six sprays	173	154	125	117	86	131
Calcium arsenate in first three sprays	155	148	153	105	84	129
Calcium arsenate in last three sprays	160	160	123	114	86	129
Calcium arsenate in sprays 1, 3, and 5	161	158	121	105	85	126
4-6-50 Bordeaux, no poison	144	138	115	107	81	117

*In every instance where poisons were applied, they were combined with 4-6-50 Bordeaux. All poisons were used at the rate of 2 pounds to 50 gallons.

†A difference of 17.3 is required for significance at 19:1 odds.

The uncontrollable variations in the replicates in this test were so great that, with one exception, no differences could be detected between the yields of plots under various treatments when the data were analyzed statistically. The exception is that the highest yielding plot is significantly superior to the check plot, but it does not differ from the other plots sprayed with an insecticide. About the only thing that can be said of this particular test is that no one treatment was superior to any other. This experiment demonstrates the danger of drawing conclusions from one season's work only, for in this instance there is almost a complete reversal of the data presented on the preceding pages.

STOMACH POISONS IN DUSTS

In 1931, two fields of Russet Rural potatoes and one of Cobbler potatoes in the muck land area at Creston, in Wayne County, were placed under experimentation. The dusts were applied with a power duster to 16-row plots and the treatments were replicated three times. Most of the applications were made at night when ample moisture was present. The basic dust was the standard 20-80 monohydrated copper sulfate-hydrated lime combination, which was mixed immediately before applying. Because calcium arsenate had shown its superiority in sprays it was the only poison used in the three tests. It was always employed at the rate of 10 pounds to each 100 of the mixed copper-lime dust. Eight applications were made between June 20 and August 26 on the two fields of Russet Rural potatoes, and six were made between June 20 and August 10 on the Cobbler field. The yields from these three fields are given in Tables 14, 15, and 16.

TABLE 14.—Dust Schedules and Yields of Russet Rural Potatoes in Field A at Creston in the 1931 Dust Tests

Treatment	Yield per acre			
	Replicate			Mean*
	1	2	3	
	Bu.	*Bu.*	*Bu.*	*Bu*
Calcium arsenate in eight dusts	228	349	311	296
Calcium arsenate in first four dusts	247	318	319	295
20-80 copper-lime dust, no arsenical	209	295	323	276
Calcium arsenate in last four dusts	174	223	258	218

*A difference of 44.9 is required for significance at 19:1 odds.

TABLE 15.—Dust Schedules and Yields of Russet Rural Potatoes in Field B at Creston in the 1931 Dust Tests

Treatment	Yield per acre			
	Replicate			Mean*
	1	2	3	
	Bu.	*Bu.*	*Bu.*	*Bu.*
Calcium arsenate in first four dusts	243	235	325	269
Calcium arsenate in eight dusts	222	253	326	267
Calcium arsenate in last four dusts	244	259	255	253
20-80 copper-lime dust, no arsenical	263	231	247	247

*A difference of 71.3 is required for significance at 19:1 odds.

TABLE 16.—Dust Schedules and Yields of Cobbler Potatoes at Creston in the 1931 Dust Tests

Treatment	Yield per acre			
	Replicate			Mean*
	1	2	3	
	Bu.	*Bu.*	*Bu.*	*Bu.*
Calcium arsenate in first three dusts	381	422	435	413
Calcium arsenate in last three dusts	381	422	340	381
Calcium arsenate in six dusts	367	394	367	376
20-80 copper-lime dust, no arsenical	367	367	367	367

*A difference of 56.2 is required for significance at 19:1 odds.

These data on dusting are presented to show the tendency of the benefit to be obtained by the addition of calcium arsenate to the standard 20-80 copper-lime dusts. The increased yield of plots which received calcium arsenate was usually sufficient to defray the cost of the material. The writer believes that the tendency to increase the yield is sufficiently great to justify the use of calcium arsenate even though the layout of the experimental plots was such that a statistical analysis did not conclusively prove the contention.

AMOUNTS OF CALCIUM ARSENATE USED IN SPRAYS

In 1933, the type of investigation was changed from the comparison of different insecticides to a program which involved different concentrations of the more desirable materials. Four-row plots containing approximately ¼ acre each were used in these tests. A four-row power sprayer mounted on an automobile chassis was used. The sprays were applied at the approximate rate of 100 gallons per acre. Calcium arsenate was used at three strengths. A series of lead arsenate plots was included also. Seven applications of spray were made between June 22 and August 4. As in previous tests, the yield from the two middle rows of each plot constituted the sample. The data obtained are given in Table 17.

TABLE 17.—The Yield of Cobbler Potatoes Sprayed with Bordeaux Mixture and Bordeaux Mixture Combined with Calcium Arsenate and with Lead Arsenate in the 1933 Spray Tests

Treatment*	Yield per acre					
	Replicate					Mean†
	1	2	3	4	5	
	Bu.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
Calcium arsenate, 2 lb. to 50 gal.	27	53	58	67	66	54.0
Calcium arsenate, 1 lb. to 50 gal.	25	42	65	66	66	53
Calcium arsenate, 1½ lb. to 50 gal.	33	25	55	63	58	47
Lead arsenate, 2 lb. to 50 gal.	31	27	52	62	63	47
4-6-50 Bordeaux, no arsenical	7	25	44	53	53	36

*In all instances the arsenicals were combined with 4-6-50 Bordeaux with additional lime added to equalize the solids in sprays containing less than 2 pounds of an arsenical.

†A difference of 8.1 is required for significance at 19:1 odds. The odds indicated are the result of an analysis of the combined data of Tables 17 and 18 because the two tests were conducted as a single experiment.

Although the yield of potatoes was exceedingly low because of the adverse weather conditions during June and July, a small difference between the yields following the various treatments existed. Plots to which calcium arsenate had been applied at the rate of 2 pounds to 50 gallons yielded slightly more than those which received the same arsenical at a weaker concentration or those which were treated with lead arsenate at the same strength.

INFLUENCE OF SPREADERS AND STICKERS

A series of spreaders and stickers was used to determine the possibility of more complete protection. In all instances 1½ pounds of calcium arsenate were combined with 50 gallons of 4-6½-50 Bordeaux. To this formula the spreaders, indicated in Table 18, were added.

TABLE 18.—The Effect of Spreaders and Stickers upon Flea Beetle Damage to Cobbler Potatoes in the 1933 Spray Tests

Treatment	Yield per acre					
	Replicate					Mean*
	1	2	3	4	5	
	Bu.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
Flour, 1 lb.	41	50	68	64	67	58
Casein spreader, ½ lb. Linseed oil, 1 pt.	33	35	69	62	64	53
Casein spreader, ½ lb. Cottonseed oil, 1 pt.	30	28	61	67	65	50
Casein spreader, ½ lb. Soybean oil, 1 pt.	28	29	62	64	55	48
No spreader	33	25	55	63	58	47

*A difference of 8.1 is required for significance at 19:1 odds. The odds indicated are the result of an analysis of the combined data of Tables 17 and 18 because the two tests were conducted as a single experiment.

As was the case with the preceding test in which various strengths of calcium arsenate were used, the yields in this test were low. The differences between the treatments used in this experiment were small but they indicate that spreaders and stickers may be of some value in increasing production. However, more work must be done on this phase of potato spraying before definite conclusions can be drawn.

OTHER CRITERIA USED IN EVALUATING TREATMENTS

Thus far, yield data have been the criterion used in evaluating treatments. In determining the effectiveness of control measures applied against any insect, it is desirable to use as many criteria as possible. This is especially true when indirect types of measurement must be used. The small size of the potato flea beetle and the peculiar habit the insect has of concealing itself when disturbed make it difficult to determine the numbers of dead and living insects in each of a series of field plots for use as criteria in determining the efficiency of each treatment. However, records of this type, although admittedly imperfect, are believed to be of some value. Another factor which must be considered is that flea beetles fly readily about the field. This flying about adds still further confusion to the work of record taking.

The different methods which have been used in addition to the collection of yield data for evaluating treatments are: (1) determining relative populations on the several plots of each test by collecting flea beetles on each plot with a definite number of sweeps with an insect net; (2) recording populations on a few plants of each treatment by the calcium cyanide method which has been described previously in this bulletin; and (3) counting the number of flea beetle feeding holes in leaf samples taken from the different plots of each experiment.

POPULATIONS DETERMINED BY SWEEPING

In 1930, the sweep-net method was thoroughly tested and found to be an undependable measure, although some valuable data were obtained. Twenty-five single sweeps of a standard insect net were made in each plot, and the captured beetles were counted. The field under experimentation in 1930 was sampled three times during the spraying season. The data are given in Tables 19, 20, and 21.

TABLE 19.—Flea Beetles Collected July 1 in 25 Single Sweeps of Net per Plot from Cobbler Potatoes in the 1930 Spray Tests

Treatment*	Beetles collected					Mean yield per acre in bushels
	Replicate				Mean†	
	1	2	3	4		
Calcium arsenate in four sprays	19	46	91	121	69	160
Lead arsenate in four sprays	24	49	51	163	72	146
6-10-50 Bordeaux, no poison, four sprays	81	89	97	101	92	156
4-6-50 Bordeaux, no poison, four sprays	31	167	83	196	119	131
Lead arsenate in first three sprays	10	57	168	283	130	144
Calcium arsenate in first three sprays	64	67	187	332	163	141

*In every instance where poisons were used, they were combined with 4-6-50 Bordeaux. All poisons were used at the rate of 2 pounds to 50 gallons of spray.
†A difference of 94.3 is required for significance at 19:1 odds.

TABLE 20.—Flea Beetles Collected July 9 in 25 Single Sweeps of Net per Plot from Cobbler Potatoes in the 1930 Spray Tests

Treatment*	Beetles collected					Mean yield per acre in bushels
	Replicate				Mean†	
	1	2	3	4		
Calcium arsenate in five sprays	78	34	27	61	50	160
Lead arsenate in five sprays	59	42	140	129	93	146
6-10-50 Bordeaux, no poison, five sprays	67	55	76	196	99	156
4-6-50 Bordeaux, no poison, five sprays	103	64	172	163	101	131
Lead arsenate in first three sprays	56	99	87	307	137	144
Calcium arsenate in first three sprays	107	144	216	143	153	141

*In every instance where poisons were used, they were combined with 4-6-50 Bordeaux. All poisons were used at the rate of 2 pounds to 50 gallons of spray.
†A difference of 92.0 is required for significance at 19:1 odds.

TABLE 21.—Flea Beetles Collected July 16 in 25 Single Sweeps of Net per Plot from Cobbler Potatoes in the 1930 Spray Tests

Treatment*	Beetles collected					Mean yield per acre in bushels
	Replicate				Mean†	
	1	2	3	4		
Calcium arsenate in six sprays	348	331	199	432	323	160
Lead arsenate in six sprays	347	621	393	575	484	146
6-10-50 Bordeaux, no poison, six sprays	517	411	707	482	529	154
Lead arsenate in first three sprays	437	651	532	741	590	144
4-6-50 Bordeaux, no poison, six sprays	498	573	469	828	592	131
Calcium arsenate in first three sprays	804	332	1101	539	694	141

*In every instance where poisons were applied, they were combined with 4-6-50 Bordeaux. All poisons were used at the rate of 2 pounds to 50 gallons of spray.

†A difference of 364.8 is necessary for significance at 19:1 odds.

When the collections recorded in Table 19 were taken, four applications of spray had been made. The first two treatments listed in the table contained an arsenical in each application. Plots treated in this way were less heavily infested than those which had not received an arsenical· also, than those which had received fewer applications of the same material.

The variously treated plots retained the same relative position in regard to flea beetle populations after five treatments as they did after four treatments had been made. There was no apparent general increase in populations during the interval from July 1 to July 9.

The data given in Table 21 were collected after a maximum of six sprays had been applied. It will be observed that the different treatments, with one exception, retained the original position in regard to the relative number of beetles collected. In each instance, fewer beetles were taken from plots which had been treated with calcium arsenate from the beginning of the season than from other plots. The populations of flea beetles on plots treated with lead arsenate were somewhat larger than those on similar plots treated with calcium arsenate. Lead arsenate appeared to remain effective over a longer period of time than did calcium arsenate, since the populations did not increase as rapidly after the use of the former was discontinued.

The data in Tables 19, 20, and 21 are of further significance because the great increase in numbers of beetles collected, as shown in Table 21, indicates that at the time these sweepings were made the adults of the new brood had just made their appearance.

POPULATIONS DETERMINED BY CYANIDE BOX METHOD

In 1931 attempts to evaluate flea beetle populations on experimental plots were made at Wooster. The calcium cyanide method which has been described in an earlier section of this bulletin (in evaluating the effectiveness of the pyrethrum test) was used. Under the conditions of that test, where a large number of samples could be taken, the data were reliable, but under the conditions of the test now under discussion, the possible number of samples was limited and, therefore, the data are not so conclusive. The beetles captured on two plants were used as a sample. The data obtained are given in Table 22.

TABLE 22.—Flea Beetles Collected July 8 on Two Plants per Plot of Russet Rural Potatoes in the 1931 Spray Tests

Treatment*	Beetles collected					Mean yield per acre in bushels
	Replicate				Mean†	
	1	2	3	4		
Lead arsenate in three sprays	23	7	1	7	10	230
6-10-50 Bordeaux, no poison, three sprays	31	9	8	16	16	236
Lead arsenate in three sprays	38	13	3	15	17	232
4-6-50 Bordeaux, no poison, three sprays	14	16	8	36	19	254
Calcium arsenate in three sprays	22	27	19	13	20	261
Calcium arsenate in three sprays	22	12	18	39	25	230
4-6-50 Bordeaux, no poison, three sprays	57	19	32	5	28	236

*In every instance where poisons were applied, they were in combination with 4-6-50 Bordeaux. All poisons were used at the rate of 2 pounds to 50 gallons of spray.
†A difference of 20.9 is required for significance at 19:1 odds.

Although the differences in populations indicated in this table were small, they correlate nicely with plot yield and with the amount of foliage damage done by the insects.

DAMAGE TO FOLIAGE

The third method of evaluating the effectiveness of sprays and dusts in controlling the flea beetles was that of collecting representative leaf samples from each plot and counting the holes made by the feeding of the insects. The required number of leaves was taken at random from a middle row of each plot, and usually the collections extended over the entire length of the plot. This method has been used throughout the project. The data are presented in tabular form. Table 23 gives the data collected in 1930.

TABLE 23.—Average Number of Holes Eaten in Each Leaf of 25-leaf Samples of Cobbler Potatoes in the 1930 Spray Tests

Treatment*	Holes per leaf					Mean yield per acre
	Replicate				Mean†	
	1	2	3	4		
	Av.	*Av.*	*Av.*	*Av.*		*Bu.*
Calcium arsenate in six sprays	190	223	248	489	288	160
Lead arsenate in six sprays	191	239	217	550	299	146
Calcium arsenate in first three sprays	444	290	557	826	529	141
6-10-50 Bordeaux, no poison, six sprays	532	499	447	776	561	154
Lead arsenate in first three sprays	307	559	644	1057	642	144
4-6-50 Bordeaux, no poison, six sprays	525	823	593	1415	839	131

*In every instance where poisons were applied, they were combined with 4-6-50 Bordeaux. All poisons were used at the rate of 2 pounds to 50 gallons of spray.
†A difference of 209.4 is required for significance at 19:1 odds.

These data demonstrate that where calcium arsenate was used throughout the season the foliage damage was reduced and the yield increased. Where no poison was used in 4-6-50 Bordeaux, the degree of foliage injury was the largest, and the yield was the smallest of all. The use of 6-10-50 Bordeaux held second rank from the standpoint of yield but fourth in the degree of foliage damage. This would indicate that the high yield was due to factors other than flea beetle control.

The two fields under experimentation in 1931 were also subjected to foliage damage studies. The results obtained at Wooster are given in Table 24.

TABLE 24.—Average Number of Holes Eaten in Each Leaf of 25-leaf Samples of Russet Rural Potatoes at Wooster in the 1931 Spray Tests

Treatment*	Holes per leaf					Mean yield per acre
	Replicate				Mean†	
	1	2	3	4		
	Av.	*Av.*	*Av.*	*Av.*		*Bu.*
Lead arsenate in first four sprays	108	252	130	84	144	232
Calcium arsenate in last four sprays	178	175	172	69	149	254
Calcium arsenate in eight sprays	187	170	107	43	154	261
Lead arsenate in eight sprays	259	202	92	64	154	230
4-6-50 Bordeaux, no poison, eight sprays	140	232	65	231	167	236
6-10-50 Bordeaux, no poison, eight sprays	286	226	51	153	179	236
Calcium arsenate in first four sprays	237	332	75	156	200	230

*In every instance where poisons were applied, they were combined with 4-6-50 Bordeaux. All poisons were used at the rate of 2 pounds to 50 gallons of spray.
†A difference of 105.1 is required for significance at 19:1 odds.

There was no great difference between the number of feeding punctures in the leaf samples taken from the various treatments. The data indicate, however, that some protection was afforded, since in one instance only did the mean number of holes in the leaves from plots treated with an arsenical exceed the mean number of holes in leaves from plots on which the arsenical was omitted.

The other field under test in 1931 was at Bolivar. The foliage damage data are given in Table 25.

TABLE 25.—Average Number of Holes Eaten in Each Leaf of 25-leaf Samples of Russet Rural Potatoes at Bolivar in the 1931 Spray Tests

Treatment*	Holes per leaf					Mean yield per acre
	Replicate				Mean†	
	1	2	3	4		
	Av.	*Av.*	*Av.*	*Av.*		*Bu.*
Calcium arsenate in last four sprays	86	69	88	128	93	169
Calcium arsenate in eight sprays	86	79	125	83	93	226
Lead arsenate in eight sprays	114	104	108	181	127	208
Calcium arsenate in first four sprays	162	143	127	159	148	205
Lead arsenate in first four sprays	142	114	184	222	166	199
4-6-50 Bordeaux, no poison, eight sprays	149	156	135	268	77	181

*In every instance where poisons were applied, they were combined with 4-6-50 Bordeaux. All poisons were used at the rate of 2 pounds to 50 gallons of spray.
†A difference of 54.7 is required for significance at 19:1 odds.

Flea beetle damage was less apparent when treatments of calcium arsenate were not started until late in the season than when the use of the material was confined to the early-season sprays. Although plots treated with calcium arsenate in the last four spray applications of the year had less visible injury at the time of sampling, the yield was not increased. This indicates that the beetles fed early in the season and that the injury done at that time affected the yield adversely.

Lead arsenate was not as efficient as calcium arsenate when applied in comparable series.

In 1932 flea beetle damage was very severe in the Wooster area; whereas at Bolivar the damage was relatively light. Foliage damage studies were made at both places. Table 26 contains data collected on Russet Rural potatoes at Wooster.

TABLE 26.—Average Number of Holes Eaten in Each Leaf of 25-leaf Samples of Russet Rural Potatoes at Wooster in the 1932 Spray Tests

Treatment*	Holes per leaf						Mean yield per acre
	Replicate					Mean†	
	1	2	3	4	5		
	Av.	*Av.*	*Av.*	*Av.*	*Av.*		*Bu.*
Calcium arsenate in last four sprays	459	375	368	454	523	436	167
Lead arsenate in eight sprays	651	387	405	313	666	484	183
Calcium arsenate in eight sprays	586	542	237	311	803	498	190
Barium fluosilicate in eight sprays	615	387	538	712	783	609	156
Calcium arsenate in first four sprays	651	835	538	671	416	622	166
Calcium arsenate in sprays 1, 3, 5, and 7	597	678	572	535	856	648	173
4-6-50 Bordeaux, no poison, eight sprays	955	565	706	661	877	753	158

*In every instance where poisons were applied, they were combined with 4-6-50 Bordeaux. All poisons were used at the rate of 2 pounds to 50 gallons of spray.

†A difference of 199.8 is required for significance at 19:1 odds.

The use of a poison in all sprays applied during the entire season or at least during the last half of it reduced the foliage damage to a greater extent than did applications made during the first half of the season or in alternate sprays throughout the season. Plots which received no poison were damaged more severely than were those to which an arsenical was applied, regardless of the number of treatments or time of application.

Damage by flea beetles to potato foliage was rather light in the Bolivar area in 1932. Table 27 gives the results obtained in the experimental spraying program of that season.

TABLE 27.—Average Number of Holes Eaten in Each Leaf of 25-leaf Samples of Russet Rural Potatoes at Bolivar in the 1932 Spray Tests

Treatment*	Holes per leaf						Mean yield per acre
	Replicate					Mean†	
	1	2	3	4	5		
	Av.	*Av.*	*Av.*	*Av.*	*Av.*		*Bu.*
Calcium arsenate in eight sprays	55	53	46	76	32	52	151
Calcium arsenate in sprays 1, 3, 5, and 7	57	79	68	71	32	61	135
Barium fluosilicate in eight sprays	80	53	76	69	70	70	123
Lead arsenate in eight sprays	65	75	110	33	87	74	126
Calcium arsenate in last four sprays	103	53	120	63	126	93	143
Calcium arsenate in first four sprays	120	165	102	47	73	101	126
4-6-50 Bordeaux, no poison, eight sprays	110	107	129	109	78	107	135

*In every instance where poisons were applied, they were combined with 4-6-50 Bordeaux. All poisons were used at the rate of 2 pounds to 50 gallons of spray.

†A difference of 41.9 is required for significance at 19:1 odds.

These results show that a poison is of value in reducing foliage damage, particularly if the plants have been well covered with the insecticide during the growing season, even though the infestation is light.

Cobbler potatoes at Wooster suffered an astonishing degree of foliage damage in 1932. The results of the spray test of that year are given in Table 28.

TABLE 28.—Average Number of Holes Eaten in Each Leaf of 25-leaf Samples of Cobbler Potatoes at Wooster in the 1932 Spray Tests

Treatment*	Holes per leaf						Mean yield per acre
	Replicate					Mean†	
	1	2	3	4	5		
	Av.	*Av.*	*Av.*	*Av.*	*Av.*		*Bu.*
Lead arsenate in six sprays	301	447	253	365	734	420	135
Calcium arsenate in last three sprays	508	299	418	509	642	475	129
Calcium arsenate in six sprays	373	427	352	690	583	485	131
Calcium arsenate in sprays 1, 3, and 5	658	656	471	669	965	684	126
Barium fluosilicate in six sprays	602	630	675	859	861	725	133
Calcium arsenate in first three sprays	867	566	715	937	959	809	129
4-6-50 Bordeaux, no poison, six sprays	757	1033	844	875	749	852	117

*In every instance where poisons were applied, they were combined with 4-6-50 Bordeaux. All poisons were used at the rate of 2 pounds to 50 gallons of spray.
†A difference of 552.4 is required for significance at 19:1 odds.

It will be noted that the data shown in this table are very inconsistent in many respects. When the results obtained were analyzed it was concluded that dependable deductions could not be drawn.

Leaf injury records were taken also on plots that had received dusting schedules. These data were collected in 1931 from two tests on Russet Rurals, fields A and B, and one on Cobblers. The data from field A are given in Table 29.

TABLE 29.—Average Number of Holes Eaten in Each Leaf of 25-leaf Samples of Russet Rural Potatoes from Field A at Creston in the 1931 Dust Tests

Treatment*	Holes per leaf				Mean yield per acre
	Replicate			Mean†	
	1	2	3		
	Av.	*Av.*	*Av.*		*Bu.*
Calcium arsenate in last four dusts	52	46	53	50	218
Calcium arsenate in eight dusts	54	80	46	60	296
Calcium arsenate in first four dusts	68	85	60	71	295
20-80 copper-lime dust, no arsenical, eight dusts	89	87	46	74	276

*In all instances where calcium arsenate was applied, it was combined with 20-80 monohydrated copper sulfate – hydrated lime dust at the ratio of 1:10.
†A difference of 30.3 is required for significance at 19:1 odds.

The figures indicate that foliage damage was not severe on any plot in the experiment and that the addition of an arsenical to the dust decreased slightly the extent of the injury.

The results from field B are given in Table 30.

TABLE 30.—Average Number of Holes Eaten in Each Leaf of 25-leaf Samples of Russet Rural Potatoes from Field B at Creston in the 1931 Dust Tests

Treatment*	Holes per leaf				Mean yield per acre
	Replicate			Mean†	
	1	2	3		
	Av.	*Av.*	*Av.*		*Bu.*
Calcium arsenate in first four dusts	81	130	98	103	269
Calcium arsenate in last four dusts	129	108	82	106	253
Calcium arsenate in eight dusts	163	86	124	125	267
20-80 copper-lime dust, no arsenical	125	107	240	157	247

*In all instances where calcium arsenate was applied, it was combined with 20-80 monohydrated copper sulfate – hydrated lime dust at the ratio of 1:10.
†A difference of 110.3 is required for significance at 19:1 odds.

The results obtained in field B were similar to those of field A, except that the damage was but slightly more severe on the plots from which the arsenical was omitted.

The foliage injury on Cobbler potatoes in the Creston area was more pronounced in 1931 than that on the Russet Rural variety. The dusting results on Cobblers are given in Table 31.

TABLE 31.—Average Number of Holes Eaten in Each Leaf of 25-leaf Samples of Cobbler Potatoes at Creston in the 1931 Dust Tests

Treatment*	Holes per leaf				Mean yield per acre
	Replicate			Mean†	
	1	2	3		
	Av.	*Av.*	*Av.*		*Bu.*
Calcium arsenate in six dusts	394	212	185	249	376
Calcium arsenate in last three dusts	269	258	257	261	381
Calcium arsenate in first three dusts	378	347	168	298	413
20-80 copper-lime dust, no arsenical, six dusts	345	389	279	338	367

*In all instances where calcium arsenate was applied, it was combined with 20-80 monohydrated copper sulfate – hydrated lime dust at the ratio of 1:10. A total of six applications was made on all plots.
†A difference of 150.1 is required for significance at 19:1 odds.

It will be noted that those plots treated six times with calcium arsenate were, on the average, less severely damaged than those on which the arsenical was omitted. Where three applications of the arsenical were made, either early or late in the season, the degree of injury was intermediate.

Leaf samples were taken from replicates 2, 3, 4, and 5 of spray-test plots under test at Wooster in 1933. The plants in replicate 1 had died before they could be sampled. This test was concerned primarily with the use of different strengths of calcium arsenate. A treatment of lead arsenate was included for purposes of comparison. The data on leaf-damage records are given in Table 32.

TABLE 32.—Average Number of Holes Eaten in Each Leaf of 20-leaf Samples of Cobbler Potatoes at Wooster in the 1933 Spray Tests

Treatment*	Holes per leaf					Mean yield per acre
	Replicate				Mean†	
	2	3	4	5		
	Av.	*Av.*	*Av.*	*Av.*		*Bu.*
Calcium arsenate, 2 lb. to 50 gal.	179	242	172	380	243	54
Calcium arsenate, 1½ lb. to 50 gal.	247	247	257	347	275	47
Calcium arsenate, 1 lb. to 50 gal.	277	282	395	448	351	53
Lead arsenate, 2 lb. to 50 gal.	260	239	195	683	354	47
4-6-50 Bordeaux, no arsenical	475	515	430	752	543	36

*In all instances where arsenicals were applied, they were combined with 4-6-50 Bordeaux mixture. In all sprays containing less than 2 pounds of an arsenical, lime was added to equalize the amount of solids in the spray.
†A difference of 134.2 is required for significance at 19:1 odds.

The use of 2 pounds of calcium arsenate to 50 gallons of Bordeaux mixture was more effective in reducing foliage damage than was the use of this poison at lower concentrations and of lead arsenate at the same strength. More damage was observed on the plots treated with lead arsenate than on those treated with calcium arsenate, even at lower concentrations.

Foliage damage studies from plots where spreaders and stickers were used with Bordeaux - calcium arsenate sprays produced the data given in Table 33.

TABLE 33.—Average Number of Holes Eaten in Each Leaf of 20-leaf Samples of Cobbler Potatoes at Wooster in the 1933 Spray Tests

Calcium arsenate, 1½ lb. 4-6-50 Bordeaux, 50 gal. and—	Holes per leaf					Mean yield per acre
	Replicate				Mean*	
	2	3	4	5		
	Av.	*Av.*	*Av.*	*Av.*		*Bu.*
Casein spreader, ½ lb. / Soybean oil, 1 pt.	247	268	197	451	291	48
Casein spreader, ½ lb. / Cottonseed oil, 1 pt.	343	326	315	284	317	50
Casein spreader, ½ lb. / Linseed oil, 1 pt.	399	278	232	364	318	53
Flour, 1 lb.	325	374	243	405	337	58
No spreader	247	247	257	347	275	47

*A difference of 134.2 is required for significance at 19:1 odds.

The increases in yield which resulted from the use of spreaders and stickers, as indicated in Table 33, did not appear to be the result of flea beetle control. There were neither practical nor theoretical differences in the degree of foliage damage to the plants under the various treatments.

THE BORDEAUX MIXTURE FORMULA

It will be recalled that practically all references to Bordeaux mixture in this bulletin have designated a 4-6-50 formula. At the time the investigations herein reported were under way, this formula was the standard recommendation for potato spraying. Later investigations by pathologists[5] and entomologists[6] have indicated that the quantity of lime recommended may be excessive and that a smaller amount might be satisfactory. A preliminary test was conducted in 1937 for the purpose of determining whether a Bordeaux formula in which the lime was decreased would serve equally well as a carrier of calcium arsenate in flea beetle control. The results indicate that a 4-3-50 Bordeaux will be as satisfactory for this purpose as the 4-6-50 formula.

GENERAL DISCUSSION OF DATA ON STOMACH POISONS

The foregoing discussion of the effectiveness of control measures has been based upon three types of data: yields, populations of beetles on plants, and numbers of feeding punctures in the leaves. Yield records were taken because the economy of a given treatment can be measured best by the yield of potatoes produced with the minimum output of labor and material. Beetle population and foliage damage studies were made because the actual effect upon the insect cannot be determined by yield alone.

The data collected in 1930 show that the largest yields were obtained from plots that received six treatments of calcium arsenate in Bordeaux mixture (Table 8). Fewer beetles were collected (Table 21) and the average number of holes eaten in the leaves taken from those plots (Table 23) was smaller than that from plots given other treatments. Both the latter criteria indicate that the increase in yield was due to flea beetle control.

In 1931, at Wooster, the highest yield was obtained from plots which received eight applications of calcium arsenate - Bordeaux (Table 9). In this case, however, the number of beetles collected (Table 22) and the number of holes eaten in the leaves taken from the same plots (Table 24) were more numerous than from other plots. By examining the data it will be seen that they are insufficient for statistical significance but that in the latter case a very definite trend is indicated.

The 1931 plots at Bolivar yielded data which showed that the highest yield was obtained from all-season treatments with calcium arsenate - Bordeaux (Table 10) and that the average number of holes per leaf was as low as that from any of the other treatments (Table 25). Population studies were not made in this instance.

Three tests were conducted in 1932. At Wooster, the highest yield of Russet Rural potatoes again resulted from eight applications where calcium arsenate was the poison used (Table 11), although two other treatments exhibited a slightly smaller number of holes in the leaves at the end of the season (Table 26). The plots at Bolivar which received eight applications of calcium arsenate - Bordeaux produced the highest yield (Table 12) and the leaves were the least severely damaged (Table 27). In the test on Cobbler potatoes at Wooster the highest yield (Table 13) and the smallest amount of foliage

[5]Tilford, P. E. 1937. Proc. Twenty-second Ann. Meet. Ohio Veg. Growers' Assoc., pp. 57-60.

[6]Sleesman, J. P. 1937. Proc. Twenty-second Ann. Meet. Ohio Veg. Growers' Assoc., pp. 69-75.

damage (Table 28) occurred on plots which received six treatments of lead arsenate – Bordeaux. Of all the tests conducted, this is the only instance where both yield and damage data were unfavorable to calcium arsenate.

When comparisons of several strengths of calcium arsenate in Bordeaux were made in 1933, the highest yield was produced by plots treated with this arsenical at the rate of 2 pounds to 50 gallons of spray (Table 18). Foliage damage of plots given this treatment was less than that of other treatments in the test (Table 32).

Seven tests have been conducted in which calcium arsenate used at the rate of 2 pounds to 50 gallons of Bordeaux mixture, applied at weekly intervals, was compared with other poisons and in different spraying schedules. In six of these tests the use of calcium arsenate at that strength produced the highest yield and in four tests the leaves from the plots so treated were damaged to a lesser degree than were those subjected to other treatments. Population studies were made in two instances. In one of these the highest yield and lowest population resulted from the weekly calcium arsenate – Bordeaux treatments (Table 21). In the other instance the yield was highest following this treatment but a slightly higher beetle population was present when the collections were made (Table 22).

One experiment was conducted in which stickers and spreaders were compared. There was a slight increase in the yield when these materials were incorporated in the spray (Table 18). There was a lack of agreement between the yields produced and the degree of foliage damage (Table 33). Just how much this condition might have been influenced by the adverse weather conditions of 1933 is not known.

In three field tests, calcium arsenate was applied in dust form. In all instances the addition of the arsenical to monohydrated copper sulfate – lime dust increased the yield (Tables 14, 15, and 16) and at the same time reduced the amount of visible damage to the foliage (Tables 23, 30, and 31).

SUMMARY AND CONCLUSIONS

Epitrix cucumeris Harris and *E. parvula* (Fab.) are the most important flea beetle pests of potatoes in Ohio. *Systena blanda* Melsh. and *S. hudsonias* Forster are of less importance but occasionally cause damage.

Life history studies of the two first-named flea beetles indicate that annually there are one complete and one partial generation of each species at Wooster. The adults begin in May to leave their hibernating quarters in the soil. The last appear as late as July. The first-brood adults, which develop from eggs deposited by the overwintered beetles, appear in the field in mid-July, and the second-brood adults appear in late August.

Under Ohio conditions flea beetle injury to potatoes is confined largely to the foliage.

Pyrethrum sprays reduce flea beetle populations but are not sufficiently effective to produce a commercial degree of control.

Data obtained in relation to crop yield, flea beetle populations, and foliage damage support one another. They indicate that calcium arsenate at the rate of 2 pounds to 50 gallons of 4-6-50 Bordeaux mixture, applied at approximately weekly intervals during the growing period, is the preferred schedule for flea beetle control on potatoes. Applications of arsenicals with Bordeaux made during either the first half or the last half of the season, likewise the use of calcium arsenate – Bordeaux alternated with treatments of Bordeaux without an arsenical, are unsatisfactory from the standpoint of flea beetle control.

When a schedule of dusts is employed, the addition of 1 pound of calcium arsenate to 10 pounds of monohydrated copper sulfate – hydrated lime is of value in flea beetle control.

RECOMMENDATIONS FOR POTATO FLEA BEETLE CONTROL

When all factors which enter into potato production under Ohio conditions are considered and when the composite findings which have resulted from the investigations reported in this bulletin are evolved, the forthcoming recommendations are made possible:

1. Begin spraying or dusting operations as soon as the hibernating beetles appear in the field. At Wooster this is shortly after mid-May.

2. In a spraying schedule, use calcium arsenate in Bordeaux mixture at the rate of 2 pounds to 50 gallons of Bordeaux.

3. In a dusting schedule, add 1 pound of calcium arsenate to each 10 pounds of monohydrated copper sulfate – hydrated lime dust.

4. Obtain as complete coverage of the foliage as possible. Both surfaces of the leaves should be protected. Adequate pressure, proper boom arrangement, and sufficient gallonage per acre are essential.

5. Applications should be made at weekly intervals. No less than six applications should be made to early varieties, such as Cobbler, and no less than eight to long-season varieties, such as Russet Rural.